学校编码：10384　　分类号＿＿＿密级＿＿＿
学　　号：19920070153659　　UDC ＿＿＿＿＿＿＿＿

厦门大学

博 士 学 位 论 文

串联动力锂电池系统均衡控制策略

Research on Equalization control Strategy for Integrated Series Connected Power Lithium Batteries

沈 汉 鑫

指导教师姓名：陈 文 芑 教授
专 业 名 称：测试计量技术及仪器
论文提交日期：2009 年 5 月
论文答辩时间：2009 年 月
学位授予日期：2009 年 月

答辩委员会主席：＿＿＿＿＿＿
评 阅 人：＿＿＿＿＿＿

2009 年 5 月

厦门大学学位论文原创性声明

本人呈交的学位论文是本人在导师指导下,独立完成的研究成果。本人在论文写作中参考其他个人或集体已经发表的研究成果，均在文中以适当方式明确标明，并符合法律规范和《厦门大学研究生学术活动规范（试行）》。

另外，该学位论文为（　　）课题（组）的研究成果，获得（　　）课题（组）经费或实验室的资助，在（　　）实验室完成。（请在以上括号内填写课题或课题组负责人或实验室名称，未有此项声明内容的，可以不作特别声明。）

声明人（签名）：

年　　月　　日

厦门大学学位论文著作权使用声明

本人同意厦门大学根据《中华人民共和国学位条例暂行实施办法》等规定保留和使用此学位论文，并向主管部门或其指定机构送交学位论文（包括纸质版和电子版），允许学位论文进入厦门大学图书馆及其数据库被查阅、借阅。本人同意厦门大学将学位论文加入全国博士、硕士学位论文共建单位数据库进行检索，将学位论文的标题和摘要汇编出版，采用影印、缩印或者其它方式合理复制学位论文。

本学位论文属于：

（　　）1.经厦门大学保密委员会审查核定的保密学位论文，于　　年　　月　　日解密，解密后适用上述授权。

（　　）2.不保密，适用上述授权。

（请在以上相应括号内打“√”或填上相应内容。保密学位论文应是已经厦门大学保密委员会审定过的学位论文，未经厦门大学保密委员会审定的学位论文均为公开学位论文。此声明栏不填写的，默认为公开学位论文，均适用上述授权。）

声明人（签名）：

年　　月　　日

摘　要

近年来，随着电动汽车的广泛应用，动力电池组的寿命问题成为制约其发展的主要因素。电池组内电池充电的不一致，是影响电池组寿命的主要原因之一。因此，电池组均衡充放电控制已成为当前研究的热点。

现有的锂电池均衡控制方式，其均衡的能量主要以相邻电池间交换为主，只对相邻电池间或电池与充电母线之间进行补偿与均衡，控制逻辑复杂，均衡效率较低，均衡控制时间长，均衡能量无法按各自的需要实现多对多电池间的补偿与均衡。本文从高频开关电源 DC-DC 转换理论和电磁理论出发，以中型锂电池组为研究对象，对锂离子电池均衡控制系统进行研究，提出一种新的能量公共池式的均衡策略－－基于多线圈能量变换技术的电池均衡充放电策略；设计了安全、可扩展的均衡控制电路拓扑与智能均衡控制策略，解决串联电池组多电池间的智能均衡能量共享，以实现串联电池组多对多的能量均衡控制，提高均衡效率，加快均衡控制过程。实验结果与理论分析一致，达到预期效果。

本文的主要研究成果：

1.提出了针对动力锂电池的能量公共池均衡策略。该方法具有控制逻辑简单，损耗低，开关应力小，允许多个电池间变换能量，允许智能控制模式，按各取所需实现多电池间的双向均衡，解决串联电池组多电池间的智能均衡能量共享，提高均衡效率，加快均衡控制过程。

2.对多线圈变压器的磁交叉耦合进行研究，提出了适合多线圈变压器的电磁分析理论，该理论能预测多线圈变压器的特性、交流阻抗与漏感，应用于锂电池均衡控制电路，建模仿真、理论分析与实验结果一致。

3.设计了基于能量公共池策略的电池均衡能量变换电路拓扑，该电路拓扑具有各取所需的均衡分配机制；均衡电流容易控制，能应用不同的均衡能量控制策略；可扩展，能适应各种规模的串联电池组。

4.提出了基于多线圈变压器的智能电池均衡控制策略，设计了基于模糊理论的自动均衡控制器，该控制器硬件结构简单，软件实现方便，均衡控制效果比较理想，实时性好，使均衡系统更加平稳、快速、安全。

关键词：动力锂电池组；充电均衡控制；多线圈变压器

Abstract

Electric vehicles have been applied extensively in recent years. However, the development of electric vehicle has been greatly restricted by the power battery lifetime. In order to improve battery life, individual cell in series connected battery string need to maintain at an equalized charge level. Therefore, many researches have been carried out on cell balancing in series connected battery string.

The existing equalization control strategy for lithium battery is focused on energy exchange between adjacent cells, which is fulfilled by charge compensation between cells and the battery bus. Thus, this strategy has some disadvantage, such as low equalization efficiency, time-consuming equalization, and compensation and equalization of energy for many to many batteries can't be realized as they want. To avoid these problems, a new technique for cell balancing has been proposed in this dissertation. Cell voltage balancing is performed using a bi-directional dc/dc converter based on multi-winding transformer. This enables additional charging capacity for the entire battery string, and improves equalization efficiency, and speed up the process of balance control. The theoretical analysis of the proposed battery equalization schemes based on multi-winding transformer can be verified by experiment results.

Innovations of this dissertation are as follows:

1. The balanced strategy using energy shared public pool for power lithium batteries is proposed for the first time, which has the advantages such as simple control logic, low dissipation, small switching stress. Furthermore, the bi-directional cell equalization using this method can be employed with intelligent control between multiple batteries, according to the cell voltage. So this method can not only solve the intelligent balanced energy sharing algorithm for series connected lithium battery strings, but also enhance the equalization efficiency and speed up the process of balancing control.

2. Based on the research on magnetic cross-coupled of multi-winding transformer, the electromagnetic analysis method is proposed, which is effective in predicting the characteristics of multi-winding transformer, impedances, and leakage inductances. Then, this method is introduced into lithium cell equalization. The validity is verified by the simulation results, theoretical results and experiment results.

3. The cell equalization energy converting circuit topologies is designed based on the algorithm of energy shared with public pool. The proposed circuit has the following advantages: The cell equalization is realized according to the cell voltage, the equalized current is easy to control by parameters, different balancing control strategy can be introduced in the proposed circuit, and it is extensible to different series connected battery strings with different size.

4. The intelligent control battery equalization algorithm based on multi-winding transformer is proposed. The automatic balancing controller based on the Fuzzy control is designed for series connected lithium battery strings. The controller has simple structure, which can be simulated easily in software. The efficiency and the performance of the real-time control are relatively good, which make the balancing control system more stable, fast and secure.

Key Words： Power Lithium battery Strings; Charge Equalization Control; Multi-Winding Transformer

目　录

Contents